III.C.1 DC-AC Inverter with Reactive-Power-Management Functionality

Objectives

- Determine the operating specifications for the energy converter.
- Determine optimum power designs to meet the system specifications derived during the first task.
- The third objective will be to determine the control components and algorithms needed to optimize the performance of the power hardware, maximizing performance and minimizing power losses and other undesirable byproducts.

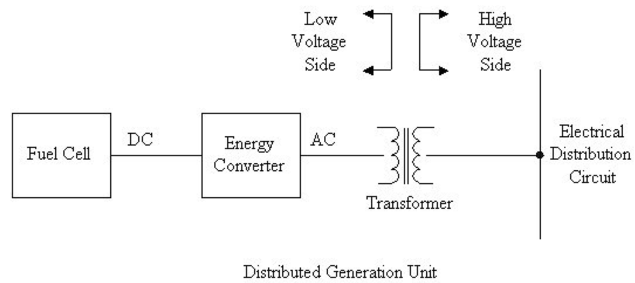

FIGURE 1. Distributed Generation Unit

Introduction

Presently, many electrical power distribution circuits have areas that are supplied with substandard power. This may take the form of voltages being out of tolerance and/or circuits being overloaded. These problems result from the impedance (real or reactive) between the generating plant and the load being higher than what is desired. If the problem is severe enough, failures in the distribution circuit will occur. These problems can be reduced, but not substantially eliminated, by increasing the size of components in the distribution circuit. An alternative to increasing the size of the distribution circuits is to add distributed generation throughout the system. Relatively small generating sources can be located close to significant loads. These generating sources will need to provide reactive power compensation (60 Hz reactive current and harmonic current cancellation) as well as real power injection into the distribution circuit.

A distributed generation unit consists of three major components as shown in the one line diagram of Figure 1. The fuel cell converts fuel to DC power. An energy converter converts the DC power from the fuel cell to 3-phase AC power that is synchronous with the power in the distribution circuit. Besides being able to inject real power generated by the fuel cell into the distribution circuit, the energy converter must also be capable of generating a substantial reactive power component. Finally, the output of the inverter is physically connected to the distribution circuit via a transformer. A single energy converter that is capable of providing real power, 60 Hz reactive power, and harmonic reactive power is less costly and considerably more efficient than providing separate units for these functions.

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Approach

- Working with a utility consultant, Mesta will develop an accurate set of specifications for the energy converter. From this information, the following items will be defined:
  - Range of real power (MW) and reactive power (MVA) that energy converters should cover to correct existing and potential future problems in distribution circuits. Regarding reactive power, a breakdown of 60 Hz and harmonic current correction needed will be derived.
  - Range of distribution circuit voltages that the energy converter may need to interface with. It is assumed that 12.7 kV will predominate, but planning for other voltages at this early stage may widen the demand for such systems.
  - Range of fuel cell voltage and power capabilities needed. This will define the interface or range of interfaces needed between the fuel cell and the energy converter.
  - Physical size and weight restraints that might enable easier movement and/or installation of equipment.
  - Operating conditions such as temperature, humidity, elevation, etc. that will affect packaging and cooling methods.
  - Environmental concerns that could put limitations on audible noise, electrical noise (RF), etc.

 - Safety concerns that will affect construction (such as preventing accidental exposure of dangerous voltage, etc. to personnel) or control safeguards (such as preventing "islanding" from occurring should there be a loss of power in the distribution circuit).
 - A communications interface and protocol to enable energy converters to be networked to a central control site where their status may be monitored and their control parameters may be altered.
- This set of specifications will be used to guide the design process. The first part of the design will be to identify major components that will make up the energy converter. A block diagram of the energy converter is shown in Figure 2. At the heart of the energy converter is a DC-to-AC converter, commonly referred to as an inverter. The inverter converts DC power originally generated by the fuel cell into 3-phase AC power that is synchronous with the voltage on the electrical distribution circuit. The inverter can pull power from the distribution circuit by producing a voltage slightly lower than the distribution circuit voltage. This power is stored in the capacitance across the DC side of the inverter. If the voltage produced by the inverter is slightly out of phase with the distribution circuit voltage, reactive power is transferred between the energy converter and distribution circuit. The converter can generate either a leading or lagging reactive power, as needed by the system. In a similar manner, the converter can also produce harmonic currents that "cancel" harmonic currents flowing in the distribution circuit.
- During Phase I, Mesta will use portions of several Mesta existing product designs to produce a conceptual design for an energy converter.
- The transformer that interfaces the energy converter with the distribution circuit will need to be characterized.
- The control components and algorithms needed to optimize the performance of the power hardware will be studied.
- Mesta will be able to test portions of the new conceptual design in a lab environment using actual hardware during Phase I.
- A final report will then be written summarizing findings during this phase, including system specifications, conceptual designs of the energy converter, budgetary cost estimates to produce the conceptually designed equipment, and test results performed to date.

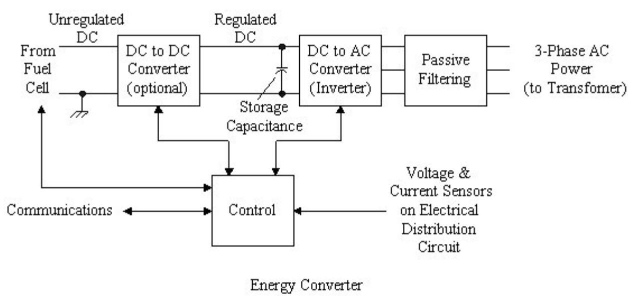

FIGURE 2. Energy Converter

Results

This is a newly initiated project (awarded 6/28/06). It will proceed for the remainder of the calendar year 2006 and the first quarter of 2007.